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OIL EXPLORATION IN AUSTRALIA

1. Introduction. - The discovery of oil in commercial quantities in Australia has been the objective of oil exploration companies for many years. Recent discoveries in Queensland could indicate that this country is on the verge of proving commercial oilfields.

A comprehensive survey of current developments was presented in a special article prepared by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development and published in the December, 1961, issue of **The Australian Mineral Industry**. With minor modifications it is reproduced below.

2. General. - Within the land areas of Australia and Papua-New Guinea, the twentyseven sedimentary basins cover 1,480,000 square miles of the total area of 3,519,000 square miles. The individual basins range in area from 4,000 to 510,000 square miles (see map on page 1079), and contain marine and continental sedimentary rocks ranging in maximum thickness from 1,000 to about 50,000 feet and including rocks of all ages from Proterozoic to Pliocene.

At present, seventy-two tenement holders have an aggregate tenement area of 2,200,000 square miles, including off-shore areas. Tenement areas range from four acres to 292,646 square miles. One joint-venture group holds a total of 381,250 square miles. Many of these large areas were granted when there was very little interest in Australian oil exploration and an absence of any general belief in the probability of finding commercial oil. Since then number of impressive shows of oil have established the presence of hydrocarbons in many parts of Australia and have given rise to a steady increase in the number of companies engaged in oil exploration.

Basic regional exploration is still only partly complete, and very little detailed investigation has been undertaken. The regional outcrop geology has been established in the New Guinea, Papua, Maryborough, Ipswich-Clarence, Sydney, St. Vincent, Carnarvon, Canning (including Fitzroy), Bonaparte, and Georgina Basins. Reconnaissance aero-magnetic surveys (flight lines at two-mile spacing) cover one-eighth of the Carpentaria Basin, half of the Bowen Basin, two-fifths of the Surat Basin, one-third of the Ipswich-Clarence Basin, the whole of the Perth and Carnarvon Basins, one-third of the Canning Basin, the whole of the Bonaparte Basin and about one-quarter of the Papua Basin. Reconnaissance gravity surveys (one station per 100 square miles) cover about one-third of the Papua Basin, one-fifth of the Carpentaria Basin, one-sixth of the Maryborough Basin, two-fifths of the Bowen Basin one-third of the Surat Basin, one-fifteenth of the rest of the Great Artesian Basin, one-fifth of the Sydney Basin, the whole of the Gippsland Basin, half of the Murray Basin, half of the St. Vincent Basin, the whole of the Perth Basin, four-fifths of the Carnarvon Basin, two-thirds of the Fitzroy Basin and one-quarter of the rest of the

Canning Basin, half of the Bonaparte Basin, and two-fifths of the Georgina Basin. Detailed gravity surveys (one station per ten square miles) have been completed only in the north-western part of the Canning Basin, the north-western part of the Carnarvon Basin and the northern part of the Perth Basin.

Regional seismic surveys and some detailed surveys have been started in the Papua, Surat, Maryborough, Great Artesian, Sydney, Gippsland, Otway, St. Vincent, Perth, Carnarvon, Canning and Bonaparte Basins. A few reconnaissance seismic traverses have been run in the Carpentaria, Bowen, Murray, Amadeus and Georgina Basins.

Stratigraphic drilling has begun in the Papua, Carpentaria, Bowen, Surat, Great Artesian, Maryborough, Ipswich-Clarence, Sydney, Gippsland, Otway, Murray, Eucla, Perth, Carnarvon, Canning and Bonaparte Basins, but only about 1,300,000 feet has been drilled in all (about one foot per square mile of the area of the sedimentary basins).

Expenditure on exploration is a useful guide to the level of activity. Since 1900 about £80 million has been spent in the whole of Australia and Papua-New Guinea - £37 million in Papua-New Guinea; £14 million in Queensland; £1.6 million in New South Wales; £4 million in Victoria; £2.7 million in South Australia; and £20 million in Western Australia. About £10 million only was spent before the 1939-45 War, mainly in Papua and Queensland. Since the War, expenditure has been concentrated in Papua (£28 million), Western Australia (£16 million) and Queensland (£13 million).

3. Government Assistance. - The role of Government in oil exploration has been to provide technical and financial assistance. On the technical side, the Bureau of Mineral Resources, Geology and Geophysics carries out geological and geophysical surveys and drilling to obtain regional data on the sedimentary basins, and undertakes laboratory investigations. The State Mines Departments control tenements and also carry out field surveys and laboratory investigations. The Division of National Mapping provides aerial photographs, photo-maps and base maps to form the basis for geological and geophysical surveys.

In addition to taxation concessions to oil exploration companies and their shareholders, since 1957, the Commonwealth Government has been subsidizing exploration for oil; £2,486,092 had been paid in subsidies for stratigraphic drilling, geophysical surveys and bore-hole logging* to June, 1961. In October, 1961, the Petroleum Search Subsidy Act 1959 was amended to include structure drilling and test drilling under subsidy, to provide for payment of subsidy for drilling on a footage basis and to extend the period of operation of the Act to June, 1964. An amount of £2,700,000 was appropriated for subsidy payments in the year 1961-62.

* The surveying of the physical characteristics of the strata in a bore.

The Subsidy Acts have been designed to increase the total amount of exploration to encourage companies to enter the field, and to ensure that subsidized exploration is adequately planned, carried out and reported upon, and that the results are generally made available within a short time. Although discoveries of oil would be the most significant immediate results of this policy, the very great improvement in the quality of the exploration work being carried out and its permanent documentation might in the long term prove more important in the success of the exploration effort on a national scale. In order to make the results of subsidized operations available, agreements have specified that the data be made available (and/or published) twelve months after the completion of field work; agreements made under the amended Act will reduce this period to six months.

The Bureau of Mineral Resources, which supervises the technical aspects of the Subsidy Act, insists on a certain minimum standard in operations; in most cases this is higher than previous

Australian standards and consistent with overseas exploration practice. For example, before 1958, very few bores were adequately logged and tested; the Bureau's insistence on logging and testing has led to the introduction of several logging units that formerly were not available in Australia. It is expected that the current improvement will continue until Australian exploration is up to the best overseas standards.

A Sedimentary Basins Study Group is being established within the Bureau of Mineral Resources to collect all available data on the sedimentary basins, to collate and compile these data and to publish review maps and reports. The data obtained in subsidized operations will provide a basis on which work can begin, but it is hoped to enlist the cooperation of State Mines Departments and of exploration companies to ensure that all data that have been obtained may be used. Much data that normally are not included in reports, such as detailed outcrop sections, basic gravity data, details of experimental seismic work and copies of seismic records, will be sought.

A Core and Cuttings Laboratory has been established in Canberra, where representative cores and cuttings from all subsidized bores and as many others as can be obtained will be available for examination. Facilities will be provided for visiting geologists to examine the material.

4. Status of Exploration. - Several promising oil discoveries have been made - at Rough Range and Meda (Western Australia), Port Campbell (Victoria), Cabawin (Queensland) and Puri (Papua) - but none of these proved commercial. Oil was discovered at Moonie (Queensland) in December, 1961. Production testing in February, 1962, produced flows at rates ranging from 184 to 1,920 barrels a day. Wells are being drilled to assess the size and productive capacity of the Moonie field. Because of the capitalization required to bring the oil to the sea-board it cannot yet be stated that this discovery will be commercial in the sense of covering costs and making profits, and this will not be known until enough wells have been drilled to establish reserves and the optimum total production rate. Gas has been found in many places; the most important shows are at Kura, Bwata, Barikewa and Iehi in Papua (all or any of which may be commercial if a suitable market can be developed); at Roma (Queensland), where the gas is being used in the local electricity generating powerhouse; at Cabawin and Glendullock (Queensland); in the Camden area near Sydney (New South Wales); and at Port Campbell and Flaxman's Hill (Victoria). These discoveries lend additional support to the opinion that oil should be present in Australia's sedimentary basins in commercial quantities.

Domestic risk capital is more readily available than previously for well-organised exploration companies, and many experienced overseas companies are for the first time taking part in, or examining the possibility of taking part in, exploration for oil in Australia. These overseas groups have brought not only funds but also equipment and experienced personnel to assist in exploration.

The main problem is still the establishment of the regional geology of the basins in precise and reliable terms, so that regional structure, formation thicknesses and rock types can be determined and the geological history established. From this the history of movement of hydrocarbons may be indicated and the more prospective areas of the basin selected for detailed exploration.

The information obtained from drilling could be improved to provide more data of potential significance, for example sonic logs* to help in interpretation of seismic records (or velocity surveys where sonic logging is not available); pressure-temperature information from all tests regardless of the nature of the formation fluid (from this the hydrodynamic characters of each sand can be determined and these may indicate areas where prospects of petroleum accumulation are good); water analyses from formation tests; more porosity and permeability determinations on cores; more cores from permeable formations; more stratigraphic control; logging of organic content and of carbonate content of cuttings.

5. Basins. - The Papua Basin which for years was the area of most intensive exploration in the Australian region is at present being less actively explored. The prospects of the basin have been enhanced by the discovery of wet gas in the Miocene and of dry and wet gas in the Cretaceous. The unconformity between the Mesozoic and the Tertiary and the thrust fault established at Puri introduce problems in exploration, but neither the Cretaceous nor the Miocene has been explored completely. The Omati Basin has sedimentary peculiarities that have not been explained and much more exploration is justified in this area.

Following the entry of several experienced American companies into the State, Queensland has been the locale of greatest exploration activity for several years. Marine Permian sediments containing oil and gas have been found in the Surat Basin, but so far the sub-surface extensions of the Lower Palaeozoic of the Georgina Basin have not been determined. The Mornington Island bores have further restricted the prospective area of the Carpentaria Basin, but examination of the Gulf is required.

The discovery of oil and gas at Cabawin and oil at Moonie in the southward sub-surface of the extension of the Bowen Basin has increased the prospects of this basin considerably; the search is now for areas of adequate sand development in or in contact with the Permian marine source rocks. It is evident that the Bowen Basin is a structural basin including only the western part of the original basin of sedimentation.

The emphasis within the Great Artesian Basin has been on the exploration of the pre-Mesozoic rocks; very little attention has been given to the salt-water sands within the marine Cretaceous although these must be rated as definitely promising. The discovery of lower Palaeozoic marine sediments at Mootwingee on the margin of the Great Artesian Basin increases the probability that the Lower Palaeozoic sequence will be found in the sub-surface of the Basin. Data on the structure of the basin and of pre-Mesozoic basins underlying it are gradually being obtained. The discovery in bores of red-bed sequences below the Mesozoic has reduced the prospects of the pre-Mesozoic basins in the east-central area of the basin. The age of these sequences is not well established.

The Wreck Island bore on the western margin of the northern off-shore extension of the Maryborough Basin revealed marine Tertiary sediments overlying basement. This discovery has not yet been followed up. In the Sydney Basin, marine fossils have been found in the Narrabeen; structural drilling targets, to help in the search for extensions of the Camdeb gas sands, have been found. A shallow stratigraphic bore at Wentworth (New South Wales) has revealed Permian sediments underlying the Tertiary in the Murray Basin. In the Gippsland Basin, marine Cretaceous sediments were found by re-examination by the Geological Survey of Victoria of material from the Hollands Landing bore. Little new work has been done lately on the St. Vincent and Torrens Basins, but a bore is planned for the Adelaide area.

Significant shows of wet gas and condensate have been found in the Otway Basin. The latest bore to test this area, Flaxmans Hill No. 1, struck wet gas, but on test it produced insufficient quantities for development. The problem is now to locate areas of adequate sand development in contact with the source beds. Submarine seepages of heavy crude petroleum have been located off the coast of south-eastern South Australia. Apart from their adding to the positive indications of petroleum in the basin, these seepages are also important in that they suggest that, whatever its origin, this petroleum is migrating through the Tertiary formations and may, in favourable locations, form pools in the permeable Tertiary sands.

The stratigraphic bores at Eyre and Gambanga in the Eucla Basin revealed shallow basement; although this confirms the thinness of the prospective sediments in these areas, it does not effectively change the prospects of this basin, which have always been regarded as low and related to the possibility of a thicker prospective sequence seawards.

* Sonic logs record the sound velocity characteristics of the strata.

The occurrence of marine Triassic sediments and traces of oil in the Permian in stratigraphic bores drilled at Beagle Ridge and the confirmation of the presence of basement rocks in the Beagle Ridge have provided additional prospective sediments to those already known in the Perth Basin, and have afforded evidence of large structural relief in the basement. The Beagle Ridge and its flank would appear to be one of the more important prospective areas in the Basin. The first deep stratigraphic bore in the central area of the Perth Basin has been drilled at Eneabba, 150 miles north of Perth.

In the Carnarvon Basin, additional seismic work in the Rough Range area apparently has not produced a structural drilling target. Seismic surveys are proposed over the Wandagee basement ridge and in the Salt Lake area, where there are numerous anticlines in Tertiary and Cretaceous sediments, and may presage the exploration of the prospective Palaeozoic sediments. Stratigraphic bores have shown traces of petroleum in both the Sakmarian Lyons Group and the Artinskian Byro Group and of marine sediments and permeable sands in both.

The Canning Basin is now known to include the deep Fitzroy Basin and at least two shallower basins in the south. The deep basin may be repeated at the east margin of the Canning Basin beyond a structurally high saddle at the south-eastern end of the Fitzroy Basin. This deep basin may continue southward to join with the north-western extension of the Officer Basin. The hinge areas on either side of these deep basins and the basement ridges between the shallower basins offer attractive areas for exploration, since Lower Palaeozoic sediments of good permeability have been proved on the Broome Ridge and marine shales in the Samphire Marsh bore. The occurrence of salt intrusions at Frome Rocks No. 1 bore and at Woolnough Hills suggest that salt-dome structure may be found in the Palaeozoic with or without expression in the Mesozoic. Although the pre-Permian has been the main exploration target, oil shows have been obtained in the Permian, and it remains a prospect in areas where contemporaneous structures are intact.

The Spirit Hill bore revealed good source rocks in the Carboniferous of the Bonaparte Basin, but the distribution of the various sequences has yet to be established. Recent marine seismic work in the Gulf may help to establish this and to give useful information as on the regional structure.

A regional gravity traverse has suggested a moderately deep Palaeozoic basin in the area east of Newcastle Waters in the Barkly Basin, and geological surveys near Camooweal suggest the possibility of the contemporaneity of the Camooweal Dolomite and the petroliferous Middle Cambrian. Geological, seismic and drilling exploration now programmed by the Bureau of Mineral Resources may change the prospects of this basin very markedly.

Regional surveys of the Georgina Basin have indicated a marine sequence, dominantly carbonate, of moderate thickness and some structural relief. Sediments appear mainly to be of shelf type, but the palaeogeography of the basin of deposition has not been established.

It has also been established that the Amadeus Basin is a structural basin with sediments mainly of shelf type, dominantly of sand and shale. It is suggested that the Georgina and Amadeus Basins are the structural remnants of a single large basin of deposition in which the Amadeus Basin represents the proximal shelf, the Georgina Basin the distal shelf or rim, and the Precambrian gneiss of the Harts Range area the location of the deep basin. The Precambrian gneiss shows strong evidence of deep burial and north-south compression at a stage much later than the high-grade metamorphism. The main problem in these two basins is to determine their structural and sedimentational histories so that possible migration directions of oil in relation to the development of structures may be assessed.

6. Results. - The net result to date is that there have been some encouraging discoveries which are partially disappointing because they have not been commercial. But there has also been,

over the past few years, a very significant improvement in the quality as well as the amount of exploration work done, and this has resulted in a very large increase in the understanding of the geology of the sedimentary basins. This in turn has enhanced the prospect of finding oil in commercial quantities.

7. Footage Drilled in the Search for Oil. - The following table, while not connected with the article above, shows details of footage drilled in the search for oil in the Commonwealth of Australia and the Territories of Papua and New Guinea during the years 1957 to 1961.

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